climate change initiative

→ CLIMATE MODELLING USER GROUP

Climate Modelling User Group (CMUG)

Current and Future work

Amy Doherty CMUG Project manager

25th March 2026

cmug cci

What is CMUG?

The Climate Modelling User Group: a project in ESA's Climate Change Initiative

UNIVERSITY OF LEICESTER

DMI
Danish Meteorological Institute

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

IPSL

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación

ECMWF

METEO FRANCE

SMHI

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

UKRI Science and Technology Facilities Council
RAL Space

THE UNIVERSITY of EDINBURGH

CMUG Aims

1. Support integration within the CCI programme

2. Foster exploitation of satellite-derived ECVs

3. Assess quality and impact of CCI ECVs

CMUG Activities

Science studies to assess quality and impact of CCI data	Engage with climate science community	Integration across the CCI programme	CCI ECV dataset user requirements
Advance ECV uncertainty characterisation	Build links with the climate modelling community	Promote CCI data use in climate models	Support model evaluation with CCI data
Provide feedback to CCI teams	Improve access to ECV datasets through tools and databases	Publish scientific papers	Gap analysis

CMUG – Scientific Studies

WP5.1 Machine Learning for Process Understanding

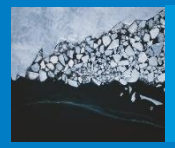
WP5.2 Vegetation Phenology

WP5.3 Land Cover

WP5.4 Ocean Biogeochemistry

WP5.5 Clouds and Aerosols

WP5.6 Snow Dynamics



WP5.7 Ice Sheets

WP5.8 Machine Learning for Wetland Methane Emissions

WP5.9 Vegetation and Hydrometeorology

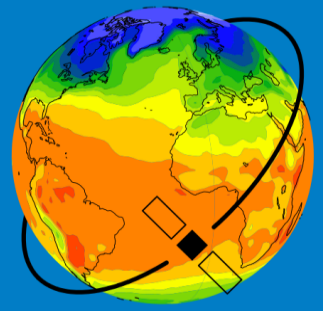
CMUG – Other activities

- CCI contributions to ESMValTool
  - *Axel Lauer, DLR*
- Climate community requirements collection and analysis
  - *Amy Doherty, Met Office*
- Foresight Report https://climate.esa.int/documents/1188/CMUG_D1.2-Foresight-Report-V4.1_8EMjc8o.pdf
  - *Richard Jones, Met Office*
- CMUG support to the future evolution of obs4MIPs
  - *Amy Doherty, Met Office / Alison Waterfall, CEDA / Claire Bulgin, U. Reading*
- Communications and outreach – *Hannah Findley, Met Office*
  - Newsletter
  - Climate Science Working Group
  - Website: Climate Modelling User Group (CMUG)

CMUG – ESMValTool development

The Earth System Model Evaluation Tool (ESMValTool):

- open-source code with extensive documentation
- community-developed
- diagnostics and performance metrics
- https://esmvaltool.org/



ESMValTool
Earth System Model Evaluation Tool

CMUG activities in support of ESMValTool:

- add recipes and diagnostics using ESA CCI datasets enabling tailored evaluation of ESMs
- explore the use of observational uncertainty characteristics for model evaluation

aerosol cci | biomass cci | cloud cci | soil moisture cci | land surface temperature cci | permafrost cci | snow cci

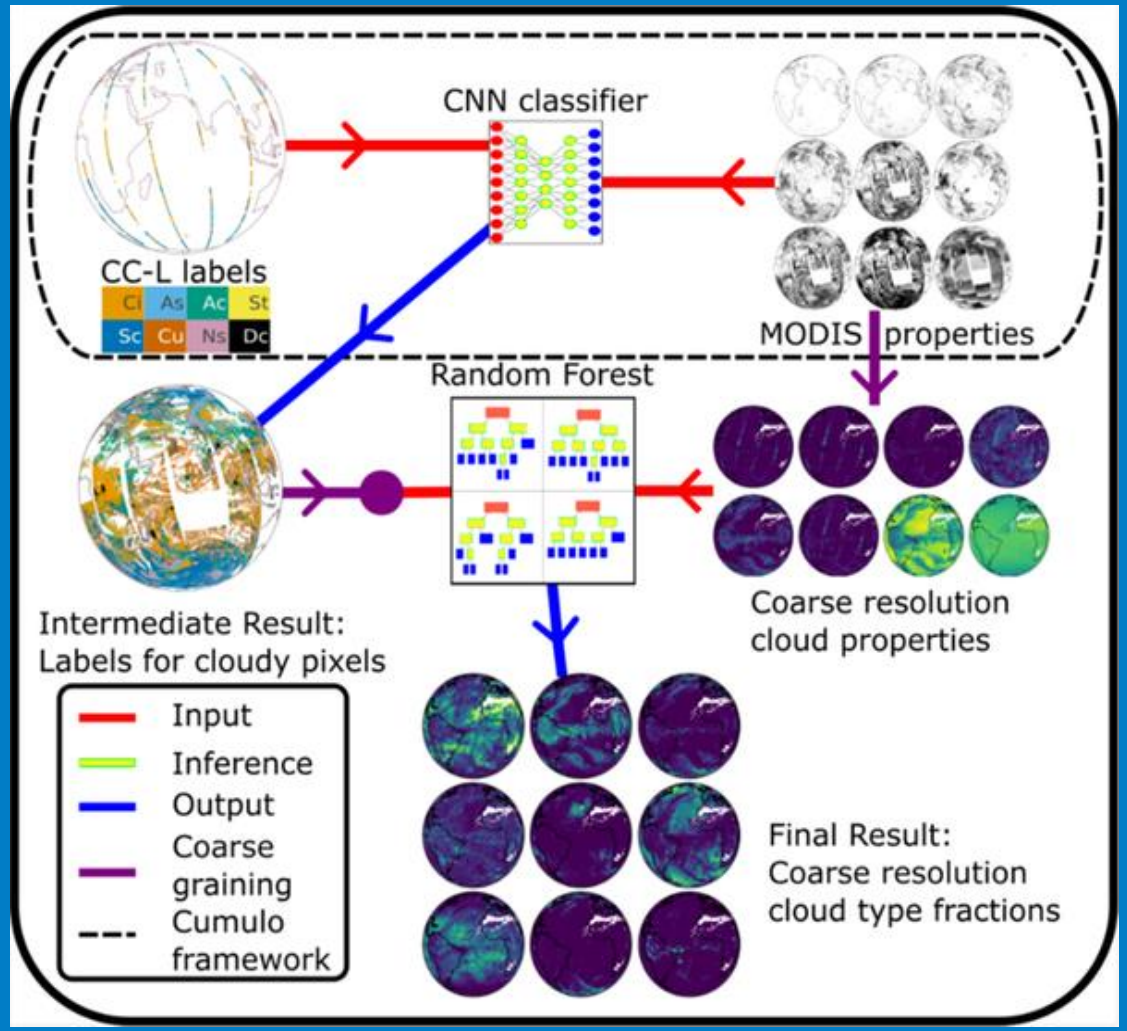
sst cci | water vapour cci | land cover cci

- See Axel's poster for more details

Machine Learning for Process Understanding

- The global Cloud Class Climatology (CCClim) dataset was produced by applying a newly developed two-stage machine learning method to 35 years of ESA Cloud_cci data

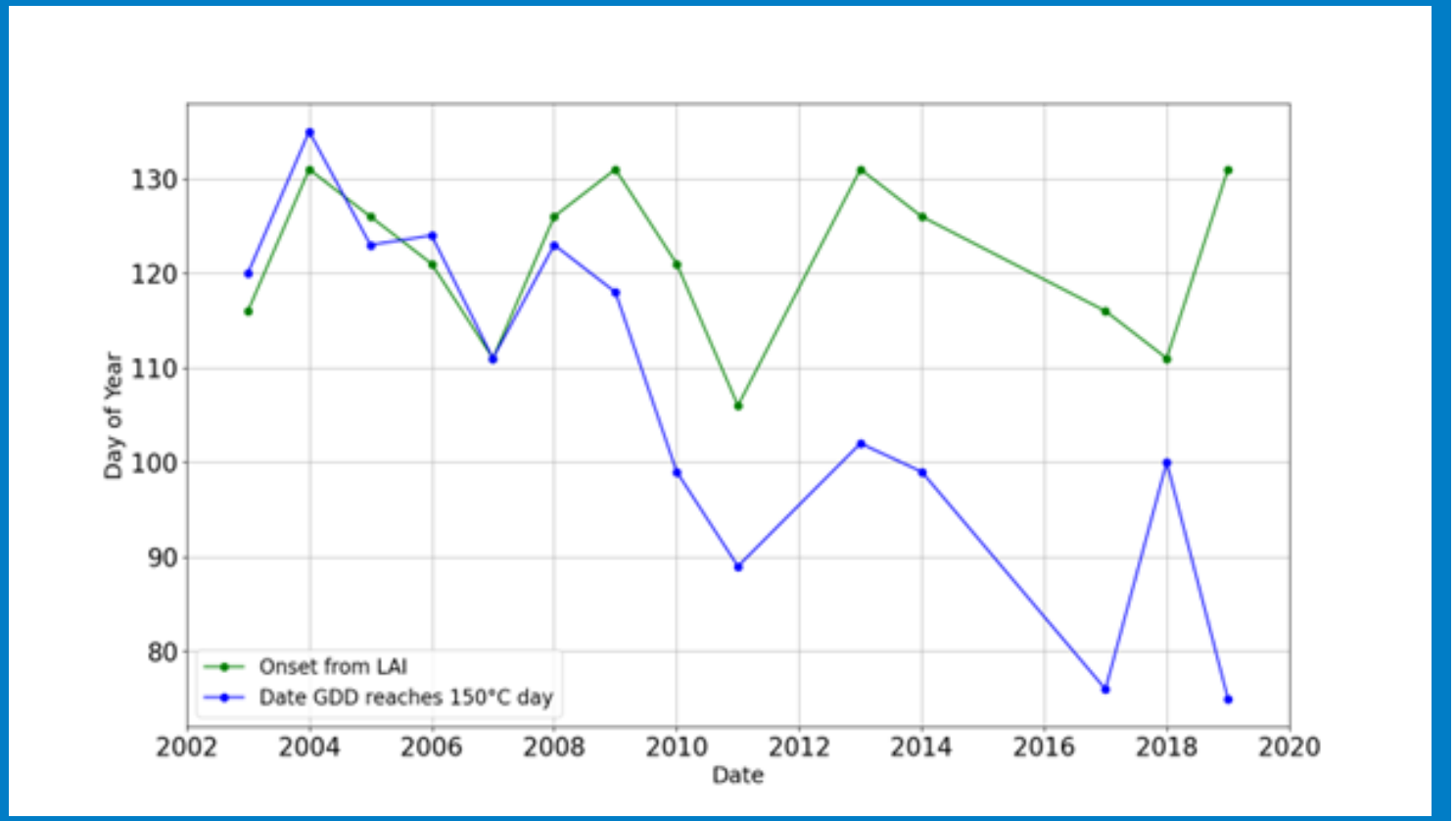
- Causal inference applied to satellite and reanalysis data quantifies drivers of marine stratocumulus cloud properties, SST, lower-tropospheric stability, sensible heat flux, and surface winds are key drivers. This reveals which processes are well explained and where factors like aerosols likely play an additional role.



Schematic of the training of the two stage machine learning process

Phenology

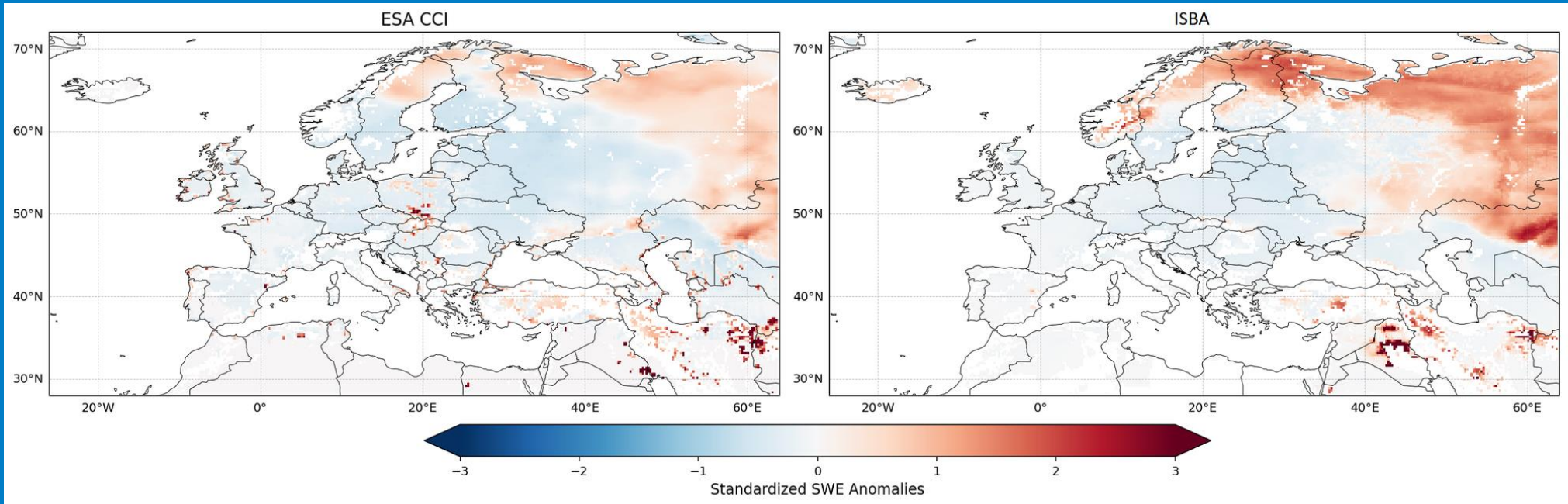
- Comparisons of vegetation onset from CCI LAI data with ground-based observations
- Vegetation onset at each location is either temperature or moisture driven, onset date relationships have been defined using growing degree day or soil moisture
- Land surface model vegetation variables evaluated using CCI data
- The GDD vs onset relationship has the potential to identify land cover types



Comparison of vegetation onset date (green) with the dates when growing degree days (GDD) reaches 150°Cday (blue). From 2003 to 2009, the two events occurred around the same time each year. In later years, the dates diverge with the GDD threshold being reached earlier, likely due to rising temperatures.

Land Cover

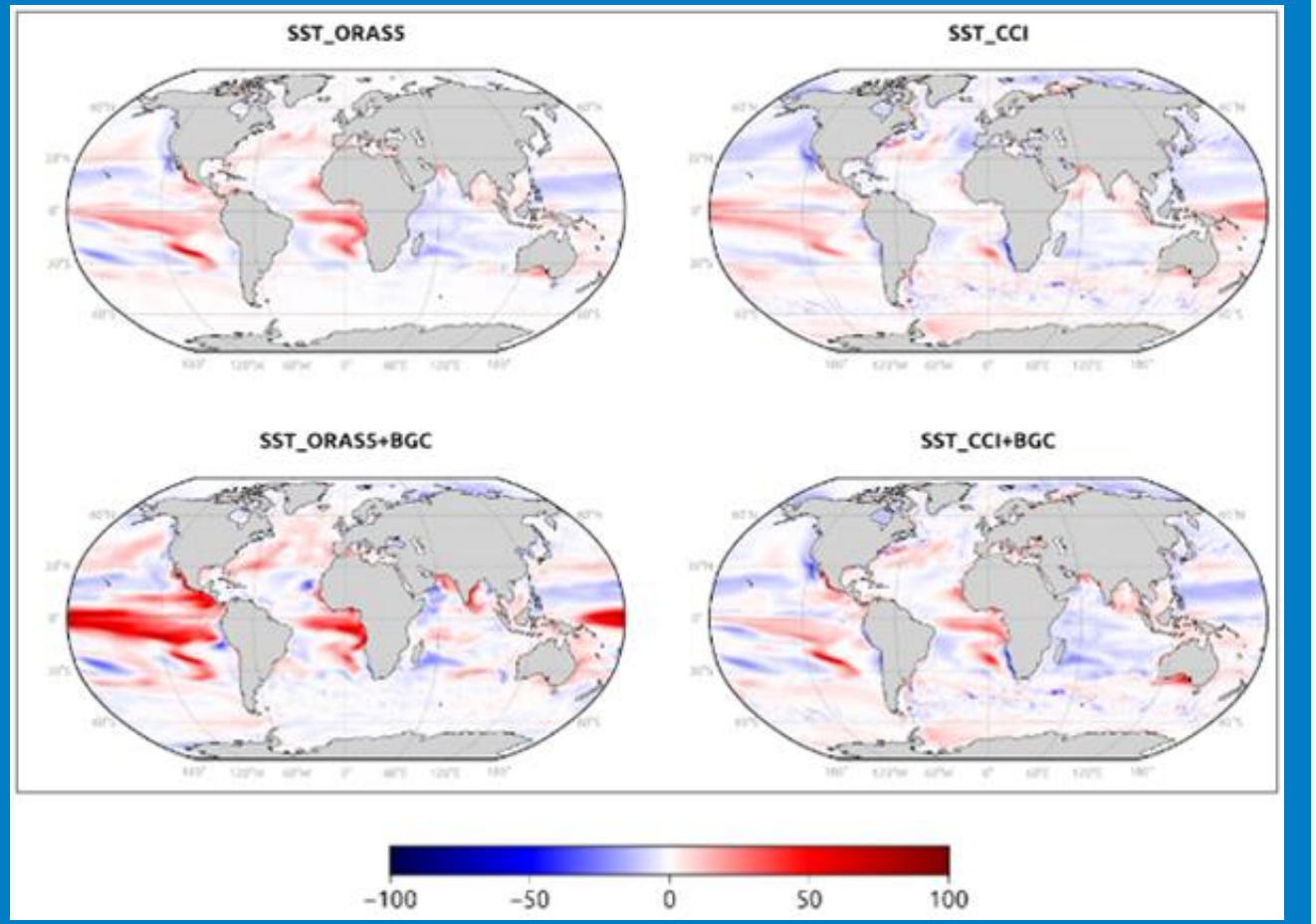
- The study assesses the impact of integrating CCI land cover (LC) data in the Météo-France land surface model
- Although the model tends to overestimate snow water equivalent (SWE), the simulated SWE anomalies are consistent with observations
- Use of CCI LC significantly reduces the root mean square difference between ISBA simulations and CCI SWE observations



Scaled SWE anomaly for the warm winter of 2020: (left) ESA CCI SWE, (right) ISBA SWE simulation using CCI LC.

Ocean Biogeochemistry

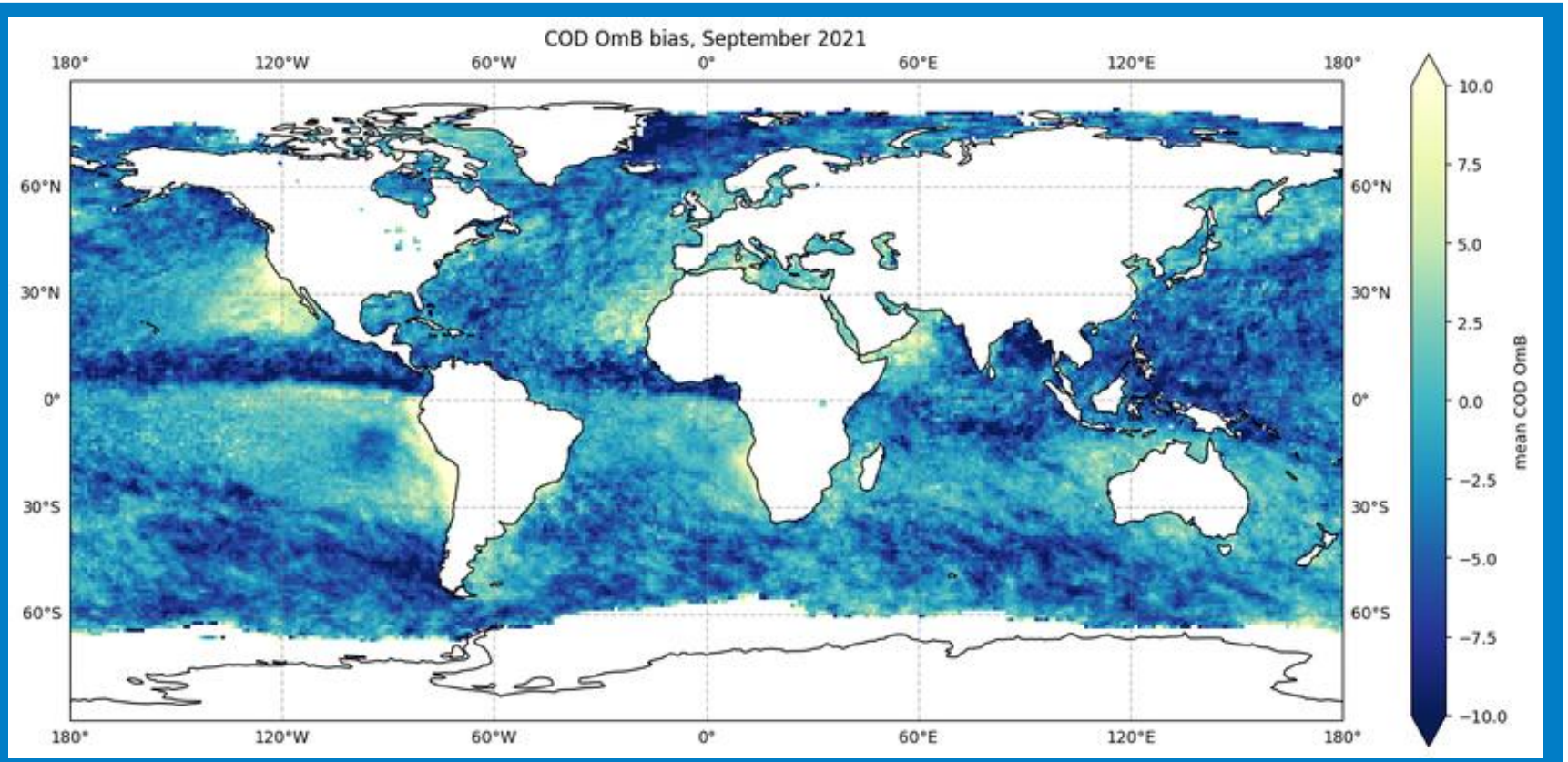
- Met Office and BSC have run ocean-ice-biogeochemistry experiments using the GloSea6/MEDUSA and EC-Earth4 models assimilating various ESA CCI datasets.
- SST and OC nudging has a small impact on primary production; larger impact found with 3D-Var and more ECVs
- Ensemble or ML techniques may show greater sensitivity to the CCI ECV datasets



The difference in annual mean water column-integrated primary production between each EC-Earth4 experiment and control.

Clouds and Aerosols

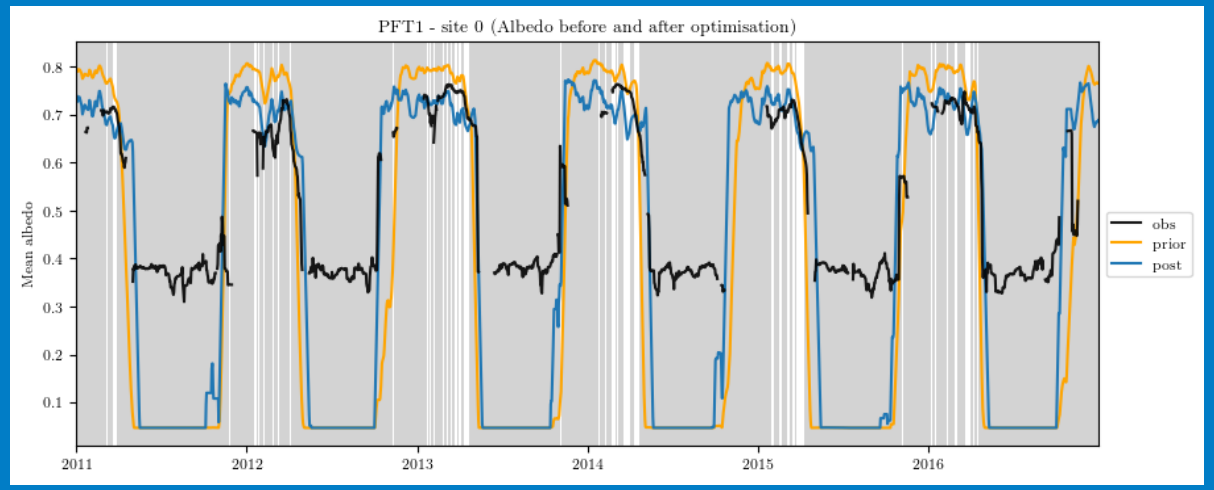
- Assimilation of CCI Aerosol Optical Depth (AOD) and Cloud Optical Depth (COD) products improves model performance
- AOD reduces bias and error compared with AERONET, COD reveals systematic cloud-related model biases that can inform future model improvements

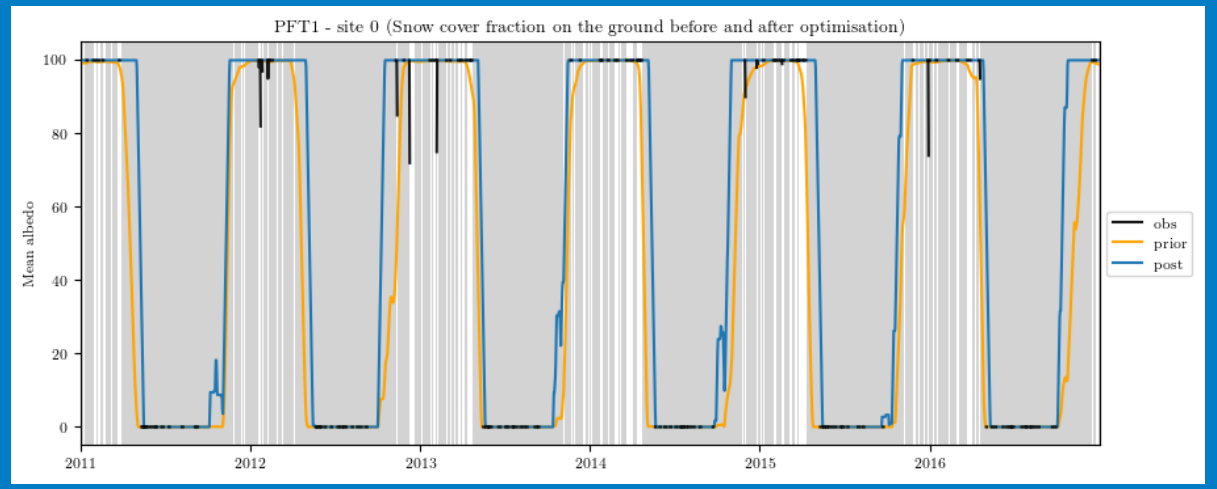


Observation minus model background mean difference for SLSTR COD observations for September 2021.

Snow Dynamics

- Updated CCI Snow products show noticeable improvements over earlier versions
- CCI Snow and albedo products used to optimise the ORCHIDEE Land Surface Model regarding snow cover fraction and snow albedo
- SCF and winter albedo better estimated with the new parameters



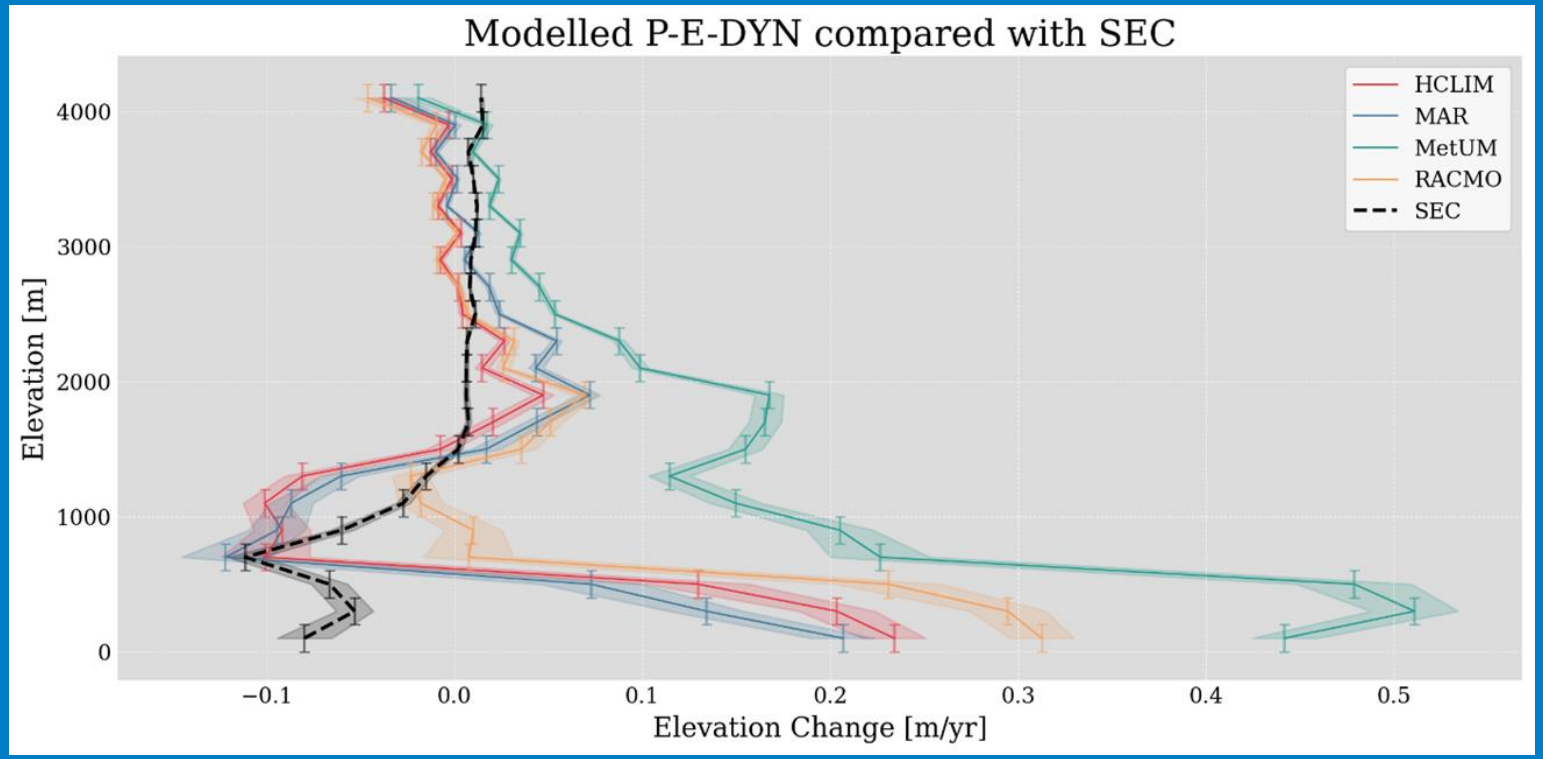


Optimisation results for one site (bare soil - PFT1): observations (albedo above/SCFG below) in black, prior optimisation result in orange, and post-optimisation result in blue. The model was only calibrated on unshaded periods.

Ice Sheets

Model and observed surface elevation change agree well at high elevations, agreement is poorer at lower elevations in both Antarctica and Greenland

Sources of uncertainty:
- precipitation schemes
- unresolved processes (e.g. katabatic winds)
- melt–refreezing dynamics



Observed Surface Elevation Changes (SEC) (black) and simulated SEC, calculated from P-E-DYN (Precipitation – Evaporation and sublimation - dynamic elevation change component), from the different regional climate models (RCMs) (orange, red, blue and green).

Machine Learning for Wetland Methane Emissions

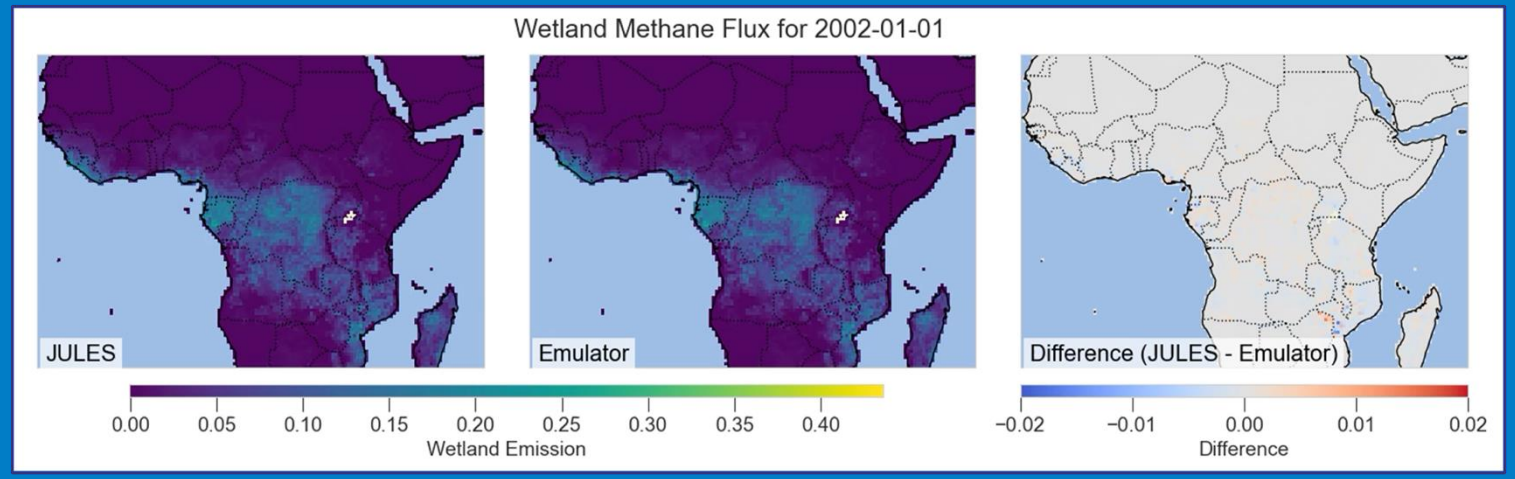
Current ensembles of JULES simulations with different driving data, temperature dependency, vegetation and wetland masks show massively different methane fluxes. This Study aims to address this by:

- developing an emulator for JULES wetland methane,
- using its explainability to show which factors matter in the model,
- drive the emulator with CCI Earth Observation data to generate wetland fluxes
- compare those to a methane inversions performed on GOSAT/TROPOMI ESA CCI data

Results:

The emulator performs well compared to JULES for wetland methane emissions, the only minor differences are on the very edges of wetland areas

Work is ongoing towards a Digital Twin



CMUG – What should the future look like?

- More CCI projects, less need for CMUG?

OR

- More CCI projects, more need for CMUG?

- Cross-ECV projects
- Interfacing Obs/Modelling projects
- Biodiversity studies
- Climate change and Cities
- Climate change and Health
- Supporting the Paris Agreement
- CMIP forcings
- Tipping Elements projects

CMUG strengths

- Broad view
- Connections between projects
- Connections with external activities
- Bringing together key perspectives
- Identifying gaps.

Way forward:

- Build on CMUG experience and CMUG partners deep familiarity with CCI
- CMUG Science studies continue
  - Strategically chosen to fill gaps in other CCI activities
  - Reach out to modelling centres with relevant expertise
- Include CCI CRG reps in CMUG consortium
- Include external partner organisations (CMIP, CORDEX) in design phase

"Inception Phase": 6 months - 1 year interacting with existing and potential new partners, identifying the current gaps in CCI activities and designing a work plan.

CMUG Questions?

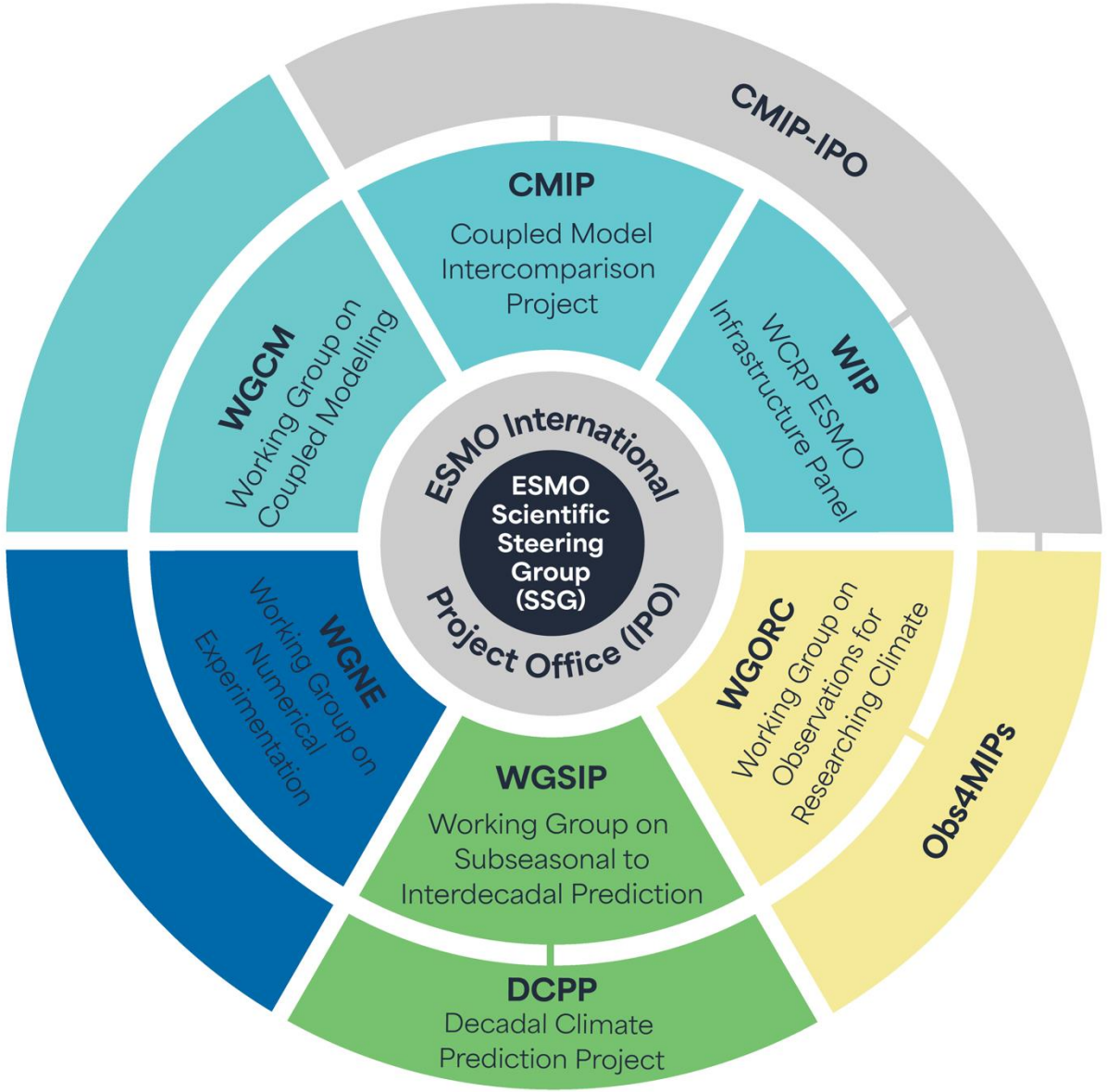
Earth System Modelling and Observations (ESMO) and the Working Group on Observations for Researching Climate (WGORC).

Amy Doherty, WGORC Co-Chair
Integration meeting 25th March 2026

Chunxue Yang, Ocean Surface Heat Flux, WGORC member
Marc Shröder, Water Vapour CCI, WGORC member
Claire MacIntosh, ESA, ESMO SSG/WGORC Liason

ESMO – a WCRP core project

Earth System Modelling and Observations



World Climate Research Programme

- CliC
- CLIVAR
- ESMO
- GEWEX
- RifS
- APARC
- Lighthouse activities
- WCRP Academy

WCRP
World Climate Research Programme

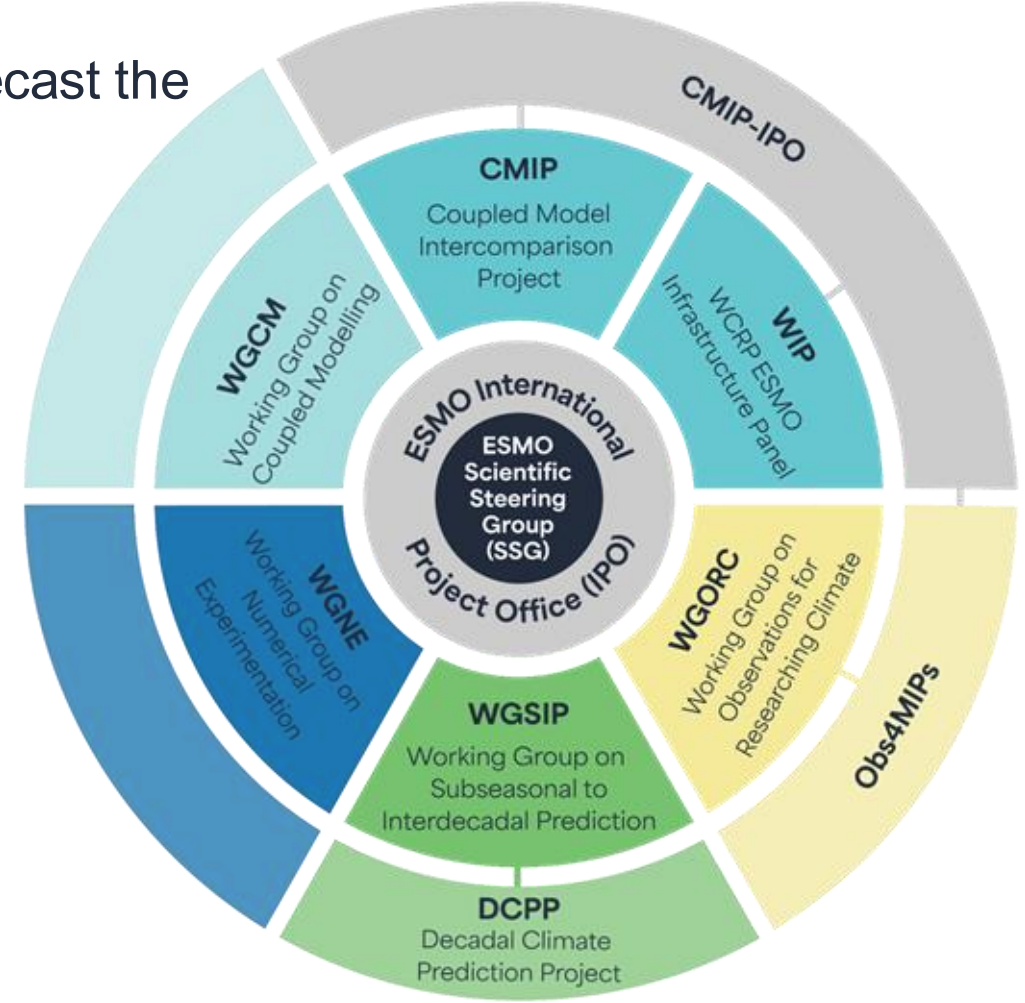
https://www.wcrp-climate.org/
https://www.wcrp-esmo.org/
https://www.wcrp-esmo.org/working-groups/wgorc
https://www.wcrp-esmo.org/projects-and-panels/obs4mips

Mission

Coordinate, advance and facilitate modelling, data assimilation and observational activities within WCRP.

Address critical gaps in our ability to monitor, predict, and forecast the climate across different time and spatial scales.

ESMO



WORKING GROUPS

- Working Group on Coupled Modelling (WGCM)
- Working Group on Subseasonal to Interdecadal Prediction (WGSIP)
- Working Group on Numerical Experimentation (WGNE)
- Working Group on Observations for Researching Climate (WGORC) => **NEW!**

PROJECTS & PANELS

- Coupled Model Intercomparison Project (CMIP)
- WGCM infrastructure Panel (WIP)
- Observations for Model Intercomparisons Project (Obs4MIPs)
- Decadal Climate Prediction Project (DCPP)
- Subseasonal to seasonal Panel (S2S)=> **NEW!**

ESMO Objectives

Advancing predictions and projections of the Earth System

on time scales from weeks to centuries and furthering model-observation integrated frameworks

Improving monitoring, understanding and attribution of climate system changes and impacts

with robust uncertainty quantification through the synthetic use of models and observations

Advancing and harnessing emerging technologies

in modelling and observations

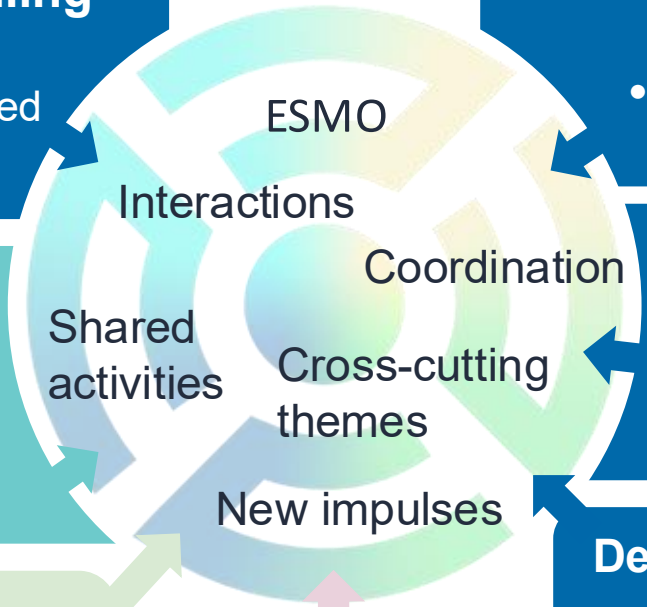
Modelling community within ESMO

Working Group on Coupled Modelling (WGCM)

- Evaluation and development of coupled climate models

Working Group on Numerical Experimentation (WGNE)

- ESMs development (design, implementation, error diagnosis, revisions)



Coupled Model Intercomparison Project (CMIP)

- Understanding of past, present and future climate changes
- Model performance evaluation

Working Group on Subseasonal to Interdecadal Prediction (WGSIP)

- Numerical experimentation for S2I variability and prediction

Decadal Climate Prediction Project (DCPP)

- Prediction of annual, multi-annual to decadal timescales

Task Team on Climate Emulators

- Brings together modeling experts interested in emulators
- Taxonomy paper in planning

km-scale climate modelling group - joint with Digital Earth

- Foster a global research network in km-scale modelling of the Earth system and individual components
- Isolate common biases/issues and ideally develop strategies

ESMO Earth System Modelling and Observations

WCRP World Climate Research Programme

Working Group on Observations for Researching Climate (WGORC)

The goal of WGORC is to advance the development and use of observations in all areas of climate science and downstream applications, working across all scales to improve understanding of the Earth system

- Co-Chairs: Amy Doherty and Douglas Rao
- 11 other members:

https://www.wcrp-esmo.org/working-groups/wgorc/wgorc-members

- First in-person meeting Dec 2025
- Panels and Task teams to be set up

Priority topics:
- Obs4MIPs
- Obs4 Extremes
- Obs4AI
- Forcings
- High res modelling
- Data rescue
- Data advocacy

WGORC is the first WCRP group explicitly tasked with considering observational system evolution and requirements.

ESMO Earth System Modelling and Observations

WCRP World Climate Research Programme

Uncertainty

Uncertainty in observations and models and at their interface

- Bridge concepts and terminology across observations and modelling
- Links with Obs4MIPs/REF; pragmatic checklists for evaluation; flexible guidelines for uncertainty documentation at different maturities

Uncertainty metadata Conventions (UNC)

- CF-compliant metadata for storing uncertainty metadata with error correlation structures
- NPL-led initiative, being beta tested through WGORC
- Beta testing sign up:

  https://bit.ly/UNC-EoI-Form

  https://comet-toolkit.github.io/unc_website/specification/draft-v0.1/unc_specification.html

WGORC Summary

Sign up to newsletter at:
www.wcrp-esmo.org/outreach

- New working group with a focus on the interface between observations and modelling
  - Obs4MIPs panel
- Currently scoping for possible additional panels / task teams
  - Capacity building; data rescue; evolution of model needs; reanalysis; extremes; uncertainties
  - Panel and task team member calls in the near future
- Aims
  - Support and communication for users and providers of climate observations
  - Accessibility and useability of observations
  - Guidance, best practice, advocacy and identification of gaps and priorities

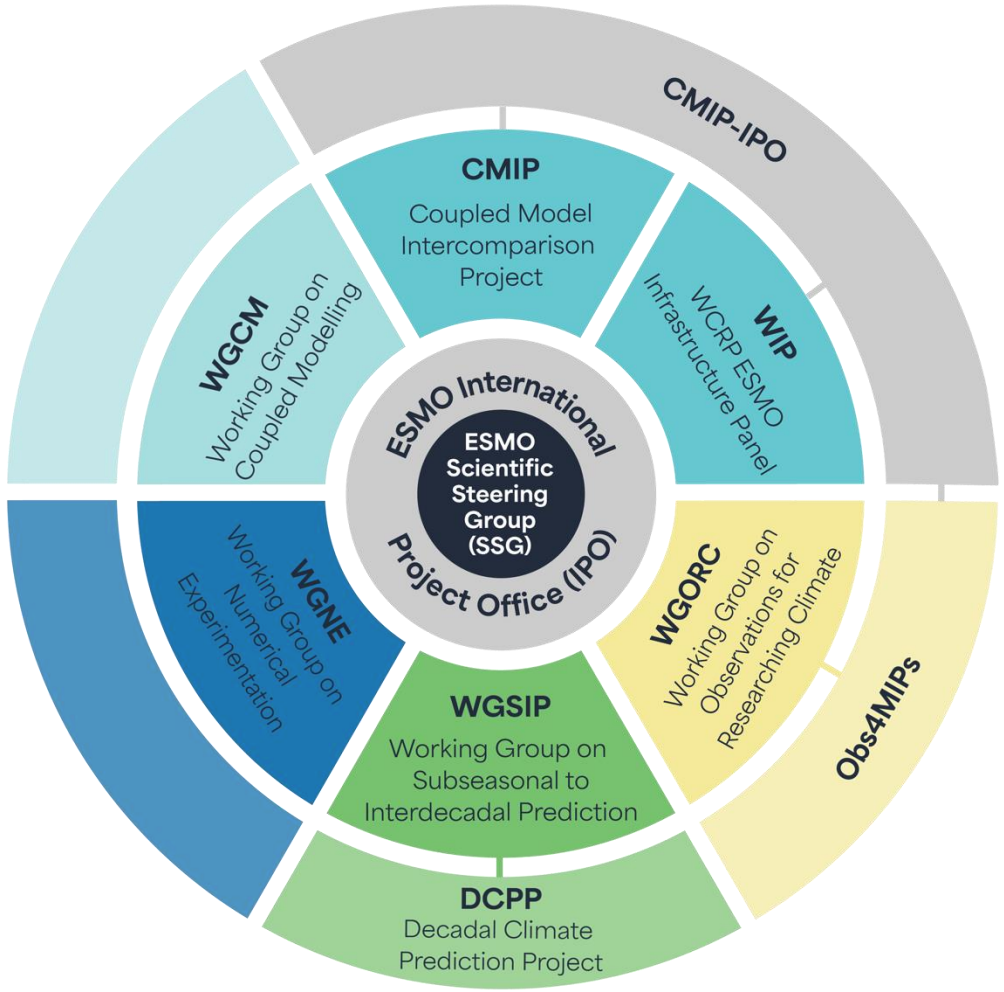
ESMO/WGORC Questions

WGORC structure: Kick-off Meeting December 2025.

Co-chairs: Yuhan Douglas Rao (North Carolina Institute for Climate Studies), Amy Doherty (Met Office Hadley Centre)
ESMO SSG Liaisons : Claire Macintosh (ESA) and Ali Cobb (ECMWF)

ESMO is a Core Project of WCRP
WGORC is a WG of EMSO
Obs4MIPs is a WGORC Panel

WGORC is the first WCRP group explicitly tasked with considering observational system evolution and requirements.



https://www.wcrp-esmo.org/working-groups/wgorc

WGORC Scoping
(part 1: Making more observations available)

- **Capacity building in generation and use of observations**
  - Working with WCRP Academy to improve access and skills
  - Lowering barriers to access: bandwidth, compute and data-format
  - Crowd-sourced and other novel data sources
- **Data rescue and advocacy**
  - Data rescue: non-satellite and satellite, useability and digitization.
  - Encourage open international sharing.
  - Highlighting at risk observations

WGORC Scoping
(part 2: Evolution of models and modelling needs)

- **km-scale models**
  - Requirement for higher resolution observations
  - Cloud-native delivery and data formats

- **Obs4AI (Machine Learning models)**
  - ML-ready data (formats, cloud-native, chunking, metadata)
  - Direct use of less-processed (lower level) data?

WGORC Scoping
(part 3: Reanalysis and Extremes)

- **Reanalysis requirements**
  - Obs4Reanalysis: Streamline and clarify existing metadata standards
  - Observations for ingestion **and** evaluation. Both need uncertainties.
- **Extremes**
  - Observational requirements around sampling, frequency, coverage.
  - Scoping with WMO/WCRP initiatives (e.g., GPEX) to define practical guidance

WGORC terms of reference (summarised)

- To **identify gaps** in the climate observations and observing systems, including novel and indirect observations, and make recommendations to address these gaps;
- To **facilitate collaboration between observational communities** across WCRP projects and activities and support coordination with external observational bodies;
- To **collect and promote recommended practices** for the generation, stewardship, quality assurance, and infrastructure of climate observations for Earth system modelling (ESM) and other applications;
- To **identify scientific priority areas** for climate observations across scales, beneficial for reanalyses, prediction, forcings, boundary conditions, model evaluations and process diagnostics, as well as other ESM-related needs;
- To promote **scientific practices for adopting emerging technologies**, such as high-resolution modelling, machine learning and AI, future observing systems that can enhance the development and application of observations for climate research.